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Art. XIX.—*On the Age of Certain Marine Deposits at Portarlington, Victoria, with a Proposed Subdivision of the Post-Tertiary Rocks of the Port Phillip Bay District.*

By J. T. JUTSON and ALAN COULSON.

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Introduction.

Some fossiliferous beds are exposed in the sea-cliffs at two localities at Portarlington (Fig. 1). The more important section is about 1 mile to the east of the pier, close to a small projecting rock of coarse-grained ferruginous grit within 100 yards of the shore, which is marked on the military map of the district as Steele's Rock. The deposits may therefore be called the Steele's Rock beds. The second section commences just to the east of the pier, and the deposits may therefore be called the Pier beds. The fossils which have been found in these two sets of beds will, we think, throw a good deal of light on the Post-Tertiary geology of the Port Phillip Bay district, and incidentally of Victoria as a whole.

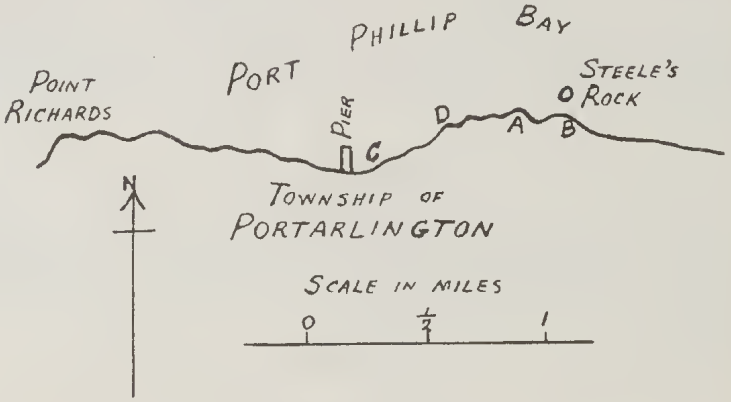

Fig. 1.—Locality plan. A—B. The Steele's Rock Section. C—D. The Pier Sections.

The Steele's Rock fossils were discovered by Mr. Andrew Blackburn, and we are indebted to him for directing our attention to their occurrence. We believe that they have only recently been exposed, owing to the extensive marine abrasion of the cliffs that is now taking place in the area mentioned. It is also possible that in the near future, by the same process, all trace of the deposits may be removed, if they happen, as appears likely, to be a remnant of a deposit formerly more widespread.

The Steele's Rock Section.

This section extends westwards from about opposite Steele's Rock for a distance of approximately 300 yards, and eastwards from the same point for about 40 yards, making a total length of 340 yards. It forms the face of low vertical cliffs, varying little and not exceeding 11 feet in height above the present beach.

At the western end, for a distance of about 300 feet, Older Basalt (now decomposed practically to a clay) occurs up to a height of 8 feet above the beach, with a very uneven surface, owing to the rocks having been extensively eroded before the deposition of the overlying sediments, which, where seen to be resting directly on the basalt, have a maximum thickness of about 6 feet. Those which pass below sea-level are almost horizontal, with an exposed thickness of about 10 feet, but towards the eastern end they appear to dip to the east, and so increase in thickness. No estimate has, however, been made of the thickness of that portion, since the main interest centres in the western portion of the section (that is the portion, about 120 yards in length, to the west of the bathing box (Fig. 2)) where the sediments consist of mottled red, brown, and nearly white sandstones and grits, with which is associated a basal band of gravel (a conglomerate in places) usually not more than 3 inches thick, but occasionally reaching 10 inches, and traceable almost continuously for 100 yards. The pebbles of the gravels are, as a rule, well rounded, and consist of white quartz, slate, and sandstone with diameters up to 2 inches. The grits and sandstones

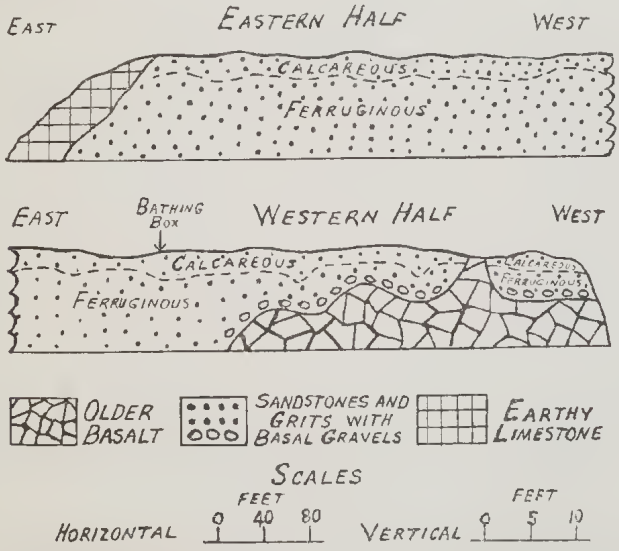

FIG. 2.—Section along the coastal cliffs at Steele's Rock, Portarlington. Some mottled clays which rest on the calcareous rocks in the eastern portion of the section, have been omitted.

are quartzose, cemented loosely together either by iron oxide or carbonate of lime, and consequently the deposits may be referred to as "the ferruginous beds" and the "calcareous beds" respectively. Where the ferruginous beds may be seen resting directly on the basalt, as in the western end of the section, they vary in thickness from 9 inches to about 5 feet.

The white and brown calcareous beds form a more compact rock than the ferruginous beds, although on weathering they develop a cavernous structure, and occur chiefly as a band at the surface of the section varying in thickness from 12 inches to 6 feet. The uppermost portions in places have been hardened by the further introduction of calcium carbonate in thin horizontal lines, with a resulting resemblance to the travertine bands in the dune limestone of Sorrento and elsewhere. Except for some broken shell fragments in the gravels, no fossils have been discovered in the ferruginous beds, but the calcareous beds are, in places, so full of fossils that the deposit may be described as a shelly limestone. The junction between the two sets of beds is uneven, and in places there are wedges up to 2 to 3 feet wide and deep of the calcareous beds in the upper surface of the ferruginous beds, forming "pockets" in the latter. In addition, there are, towards the western end, several small irregular patches, measuring in different directions from 6 to 18 inches, scattered through the ferruginous beds.

About a chain west of the bathing box (Fig. 2) the decomposed Older Basalt disappears owing to its deeper erosion. Proceeding eastwards, the sediments consequently increase in exposed thickness, and, as a whole, become more ferruginous and coarser-grained, with numerous thin bands of water-worn pebbles, mostly quartz, and with much current bedding. At the eastern end, they appear to dip to the east at about 30 degrees, under a yellow earthy limestone, which weathers into a nodular, uneven mass. The calcareous beds surmount the ferruginous beds practically all the way. The sandstones, grits, and earthy limestone are unfossiliferous so far as our observations go. In places, in the eastern portion of the section, there are above the calcareous beds, clayey gritty beds, much weathered, and from 2 to 3 feet thick. These have not been carefully examined, and no fossils were observed in them.

At each end of the whole section, there are small recent marine sediments which have been laid down with sea-level as at present, and which at the eastern end of the section rest on the denuded edges of the yellow limestone, and contain pebbles of that rock.

About 100 yards in a straight line west of the western end of the main section is a small, low, projecting point, composed of a deep red sandstone, which weathers out into rough blocks. No fossils have been found in these rocks.

In regard to the relations between the calcareous and ferruginous beds of the Steele's Rock section, the first impression is that they are quite distinct from each other, and are separated by an unconformity, the lower beds probably being of Kalimnan age, and the upper, Recent or late Pleistocene. Close observation, however, shows that the two rocks merge into each other without any physical break, that they are composed of exactly similar materials except as regards their respective cements, and that even the distinctive colours of the beds merge into each other almost imperceptibly. This conclusion was arrived at from a study of the general line of contact of the two groups, and it is placed, in our opinion, beyond doubt (1) by the occurrence in the western portion of the already noted small calcareous fossiliferous patches in the heart of the ferruginous beds, the former having direct continuity on all sides with the latter without being mere cavity filling; and (2) by the occurrence, at one or two places in the western portion of the section, of scattered recent shells more or less from top to bottom of the sediments.

The eastern portion of the section appears very strikingly to contradict the conclusion that the two beds really form a homogeneous whole, but careful examination shows that the apparent unconformity does not exist, the explanation being that the carbonate of lime is a surface deposit, probably derived from the solution of the shells which originally occurred in the lower beds. Similarly, we find throughout the whole section that the carbonate of lime is the preserver of the fossils.

The Pier Sections.

The relevant sections commence within 100 yards east of the pier, and extend for about half a mile eastwards as sea-cliffs. The greatest exposed thickness of the sediments is not less than 25 feet, but there is much variation in this respect. They rest on the irregularly eroded surface of the Older Basalt, and consist usually of medium and occasionally coarse-grained quartzose sands, with a coating of light-brown iron oxide, not as a rule, however, in sufficient quantity to cement the sands into a firm rock. Gravels, basal and otherwise, composed of well rounded pebbles, up to 3 inches in diameter, of quartz, slate, and sandstone in thin bands are associated with these sands. At one place, the typical light-brown sediments passed upwards without any physical break into a white calcareous-looking rock, generally similar to that of the Steele's Rock area. No fossils were found in this white patch, but the ferruginous beds, although generally unfossiliferous, yielded in three separate places small marine molluscs of species now living.

We originally had some doubt as to whether the shells had not been carried to their present positions by human agency, but the number of outcrops, and their mode of occurrence, have

satisfied us beyond reasonable doubt that they are actually imbedded in the rocks, although mostly found in small masses projecting 2 or 3 feet from the main body of the cliffs above. The shell bands are usually not more than an inch thick, and their traced length usually does not in any individual outcrop exceed 8 feet. At least seven distinct outcrops have been noted, and four of these occur in a length of between 30 and 40 yards in the most westerly portion of the section close to the pier. The height of the outcrops above the beach varies from about 15 to 25 feet. There may consequently be more than one bed of shells, but this point is difficult to determine.

Fossil Contents.

Fossils collected from the Steele's Rock section have been kindly examined for us by Mr. F. Chapman, A.L.S., F.G.S., and his determinations are as follows—

PELECYPODA

Arca (*Barbatia*) *fasciata* Reeve
Mytilus planulatus Lam.
Brachyodontes rostratus (Dunker)
Chlamys bifrons (Lam.)
(?)*Diplodonta* sp.
Cardium racketti Don.
Eumarcia nitida (Q. and G.)
Pseudarcopagia victoriæ (Gatl. and Gabr.)

GASTEROPODA

Patelloida conoidea (Q. and G.)
Monodonta ? *constricta* Lam.
Cantharidella cf. *liberiana* (Crosse)
Polinices conicus (Lam.)
Bittium granarium (Kiener)
Diala lauta Adams
Pyrazus diemenens's (Q. and G.)
Nassarius victorianus (Iredale)
Neothais succincta (Martyn)
Conus anemone Lam.
Bullaria botanica Hedley

All the specimens determined are of species now living.

Age of the Beds.

So far as examined, there are no extinct species, so that the rocks are apparently younger than the Werrikooian (the typical basal bed of which contains about 5 per cent. of living species in a molluscan fauna of nearly 200 species) which Singleton (1935, pp. 132, 134) regards as of Upper Pliocene age. The Portarlington beds must therefore be regarded as not older than Pleistocene, and for reasons stated below, we place them tentatively as Lower Pleistocene.

Correlation with other Deposits of Tertiary or Post-Tertiary Age of the Port Phillip Bay District.

Rocks, generally similar lithologically to the ferruginous portions of the Steele's Rock and Pier sections, occur as a fringe around the Bellarine Peninsula, as, e.g., at Clifton Springs, Portarlington (west of the pier), St. Leonards, Ocean Grove, Lake Connewarre, and over extensive areas of the interior of the peninsula. These deposits have not, so far, yielded any fossils, but they overlie, in places, fossiliferous Tertiary deposits of Kalimnan and of greater age. Most of the upper beds above referred to were regarded by Hall and Pritchard (1893, pp. 2, 9, 19) as of probably Upper Tertiary age. These upper beds have apparently never been carefully examined, so that, at present, it cannot be stated whether or not they are conformable to the lower proved fossiliferous ones; nor, in the absence of fossils, can they be correlated, except provisionally, with the beds described in this paper.

Beds, lithologically similar to the upper deposits just referred to of the Bellarine Peninsula, and not yet proved to be fossiliferous, occur on the eastern side of Port Phillip Bay, as at Mornington, Frankston, Beaumaris, and Brighton; and also inland, as at Green Gully (Keilor), Northcote, Preston, and Brunswick. They also, in places, rest on fossiliferous Tertiary deposits of Kalimnan and of greater age, but in other places they lie directly on the Silurian. These deposits, owing to their apparent conformity with the underlying fossiliferous beds where the latter occur, were, like those of the Bellarine Peninsula, generally regarded as Upper Tertiary. (Hall and Pritchard 1897, p. 223) as to the Brighton and Beaumaris beds; (*ibid.*, p. 213) and Crespin (1925, p. 103) as to the Green Gully beds; and Kitson (1900) and Chapman (1914 and 1921) as to the Frankston beds). It is, however, of considerable interest to note that T. S. Hart (1893, p. 156) many years ago recorded his opinion that in the Brighton district the fossiliferous lower rocks were separated from the upper, apparently unfossiliferous ones, by a distinct unconformity. Hall and Pritchard (1897, pp. 190 and 202) later examined these beds, and whilst they agreed that unconformities existed, they considered them to be small local irregularities without indicating any difference in age of the two sets of beds.

Beds of much the same type outcrop at Studley Park, from which a fossil has been obtained, which Chapman (1923) regards as being probably indicative of Kalimnan age; but more evidence is desirable before coming to a definite conclusion on this point, and therefore these Studley Park beds are not here taken into consideration. Should, however, the Kalimnan age of these beds be confirmed, there is the possibility of overlying unfossiliferous beds having been removed by erosion.

Further examples of apparently unfossiliferous sediments resting on fossiliferous Tertiary rocks are indicated by the Newport Bore (Hall and Pritchard, 1897, p. 215), and by the Altona Bore (Hall and Pritchard, 1897, p. 218; and Thiele and Grant, 1901, p. 145).

All these uppermost apparently unfossiliferous beds are for the present grouped together by us, and their tentative classification would be either Werrikooian or Lower Pleistocene. As between these two ages, we suggest the latter, since we place the Portarlington beds in the Lower Pleistocene, and there is a general resemblance to the Portarlington beds in lithology and mode of occurrence.

The Royal Park beds are all fossiliferous, although scantily so in their upper portions, and are regarded by various authorities as being not younger than Kalimnan, so that that area need not be further considered here, except to point out that it is possible that there were originally overlying non-fossiliferous sediments which have been removed by erosion.

From an exhaustive examination of the records of the deep bore at Sorrento, Chapman (1928, p. 180) regarded the limiting depths of the Pleistocene as between 112 feet and 489 feet in the bore. He states that the series contains mollusca, which are all of recent species, that the basal bed (489 feet) exactly resembles estuarine beds found at slight depths at the mouth of most Victorian rivers, and that the dune rock found within the limits mentioned is consolidated exactly like the old Sorrento limestone, which contains extinct marsupials. Chapman (*loc. cit.*), whilst considering that the bore records afford no tangible palaeontological evidence on which to work in regard to the delimitation of the Werrikooian division, yet, in lieu of better evidence, takes the depth from 490 feet down to 520 feet as probably comprised within the Werrikooian, but he points out that in the series allocated provisionally to the Werrikooian, at the depths stated above, the deposits show a good deal of relationship to the Pleistocene.

Any correlation of the Portarlington beds with the deposits of the Sorrento bore must, we think, be restricted to the deposits between 112 feet and 520 feet. The Dune Limstone occurs between 112 feet and 489 feet, and, although it cannot be said that the deposits (or at least those at a moderate depth) are contemporaneous with the Dune Limestone outcropping at Sorrento, Queenscliff, Point Lonsdale, and Barwon Heads, yet if a conclusion, however tentative, must be drawn, the affinities of the bore beds between 112 feet and 489 feet certainly appear to be nearer to the surface Dune Limestone than to the Portarlington beds, which we regard as considerably older than the surface Dune Limestone.

From the slender evidence available, there appears to be a closer relationship between the Portarlington beds and those of the Sorrento bore between 490 feet and 520 feet, which consist of an ochreous sandy clay and consolidated microzoic sandstone (Chapman, 1928, p. 180); and Chapman, as already mentioned, is doubtful whether they should be placed in the Werrikooian or the Pleistocene. For the reasons stated, we incline to the latter age.

The fossiliferous beds discovered by Mulder (1901) beneath the Newer Basalt at the Moorabool railway viaduct (which are about 20 miles to the west of the Portarlington beds, and which have an elevation above sea-level of probably about 150 feet) were regarded by Tate as of Older Pleistocene age, although Mulder, from their general resemblance to the marine beds of south-western Victoria, which Dennant had classified as Upper Pliocene, placed them in that division.

The followng are the fossils recorded by Mulder, with the nomenclature (not determinations) brought up to date, for which we are indebted to Mr. Chapman:—

Neothais succincta (Martyn)
Verconella tasmanicnsis (Adams and Angas)
Nassarius lyrella (Beck)
Nassarius victorianus (Iredale)
Pyrazus diemenensis (Quoy and Gaimard)
Turritella clathrata (Kiener)
Polinices aulacoglossa P. and V.
Bombicium melanostoma (Gmelin), var. *plana* (Q. and G.)
Ostrea virescens Angas
Chlamys antiaustralis (Tate)
Mytilus planulatus Lam.
Bassina paucilamellata (Dunker)
Pholas australasiae Sow.
Teredo or *Nausitoria* sp.
Magellania flavescens Lam.

Mulder's list also includes *Ostrea mordax* Gould, *Mytilus magellanicus* Lam.(?), *Corbula scaphoides* Hinds, and *Balanus* sp., but Mr. Chapman queries the identity of *Ostrea mordax* Gould and *Mytilus magellanicus* Lam., and also points out that *Corbula scaphoides* Hinds, if typical, belongs to the genus *Aloidis*, but specimens require revision. He has also referred us to the record by Dennant and Kitson (1903, p. 142) from the same locality of *Cancellaria granosa* (Sow.). He concludes that all the forms seem to belong to living species.

Singleton (1935, p. 132) places the Werrikooian in the Upper Pliocene, the type beds being those of south-western Victoria, already referred to. He states (p. 133) that the Moorabool viaduct beds are perhaps referable to the Werrikooian, as also the sandy clays and sandstone at about 500 feet in the Sorrento

bore, but he considers it difficult to draw a boundary between Tertiary and post-Tertiary sedimentation, and that some of the strata referred to the Werrikooian may be Pleistocene. We gather, however, from Mr. Singleton that he now tends to regard the Moorabool beds as belonging to the Werrikooian rather than to the Pleistocene; but the age is still apparently in doubt. In any event, by reason of the facts that lithologically there is considerable similarity between the calcareous portions of the Steele's Rock section and the Moorabool beds, and that, as indicated below, we regard the Portarlington beds as older than the Newer Basalt, we consider that there is a close relationship between the Portarlington and Moorabool beds, but that the latter are slightly older than the former, whether the Moorabool beds are ultimately found to be Werrikooian or Pleistocene. At present we incline towards placing both deposits in the Pleistocene, notwithstanding the difference in altitude above sea-level of their respective outcrops, since, in a distance of 20 miles, that difference can no doubt be explained by the occurrence of an irregular erosion surface at the time of the deposition of the beds, or by unequal uplift, warping, or faulting, or by the combined action of these two forces. The Portarlington beds, and provisionally also the Moorabool beds, are placed by us in the Lower Pleistocene with the difference of age indicated above.

The Portarlington deposits we consider to be older than, and separated by, a pronounced period of erosion from the Newer Basalt for the following reasons:—The sediments are apparently either of the same age or closely related to the similar deposits of the Bellarine Peninsula, of the eastern shore of Port Phillip Bay, and of the country around Melbourne. The basalt does not reach Portarlington or the eastern shore of Port Phillip Bay, but it occurs in the valley of the Yarra and some of the tributaries of the latter; always, however, as flows after the dissection by stream action of the deposits, which for the purpose of this discussion are assumed to be of the Portarlington type. Nowhere in the vicinity of Port Phillip Bay or elsewhere, so far as we are aware, do sediments of the type mentioned rest on the basalt; and the Moorabool beds are below the basalt. The greater part of the Newer Basalt series is regarded by Singleton (1935, p. 134) as Pleistocene. Owing to the probable periods of erosion between the deposition of the Portarlington rocks and the effusion of the Newer Basalt, and between the latter and the Dune Limestone, the basalts are assigned to the Middle Pleistocene.

The Dune Limestone of the Sorrento Peninsula, Queenscliff, Point Lonsdale, and Barwon Heads we consider to be younger than the Newer Basalt, and, consequently, considerably younger than the Portarlington and Moorabool beds. At Barwon Heads the limestone rests upon the basalt, and nowhere in the wide area

of the Port Phillip Bay district, so far as known to us, are sediments of the Portarlington type or basalt of the Newer Basalt series found resting on or interbedded with the Dune Limestone. The latter we place partly in the Pleistocene, owing to the finding of the remains of an extinct kangaroo in that rock (J. W. Gregory, 1901, who considered the lower part of the limestone to be late Pliocene or Lower Pleistocene), but the limestone probably passes into Holocene. (See Singleton, 1935, p. 133.) There has been deep dissection of the Newer Basalt of the Port Phillip area, and it appears most probable that the Dune Limestone was not deposited until that dissection had advanced to a considerable stage, although there is no direct evidence as to that. The Dune Limestone in its lower portions is therefore assigned by us to the Upper Pleistocene, and in its upper portions to the Holocene, although we are at present unable to indicate any line of demarcation between the two divisions.

The thin marine beds fringing the coast of Port Phillip Bay, e.g., at the Yarra mouth, Altona, Little River, Point Henry, Point Lonsdale, Rosebud, Carrum, and Elwood, from their mode of occurrence and fossil contents, are regarded by us as all approximately of the same age. The same features suggest that they are younger than both the Newer Basalt and the Dune Limestone, and this inference is confirmed at Altona, where they rest upon the Newer Basalt, and in the Point Lonsdale district, where they lie upon the eroded surface of the Dune Limestone. The occurrence of the latter rock at considerable depths in the Sorrento bore (see Chapman, 1928, pp. 7 to 10 and 180), also points to the same conclusion. We therefore place these marine deposits in the Holocene. Singleton (1935, p. 134) thinks that the Altona beds are probably not as old as Pleistocene.

The limited deposits of freshwater limestone at Lara and Limeburners' Point, Corio Bay, Geelong, rest upon the Newer Basalt, but their relation to the Dune Limestone is not clear. Pritchard (1895, p. 40) appears to incline to a Pleistocene age for these freshwater limestones rather than Newer Pliocene as suggested by McCoy. In view of the stratigraphical position assigned by us to the Newer Basalt, we place them in the Pleistocene, but whether they are late Middle Pleistocene or Upper Pleistocene cannot at present be stated. The amount of dissection by stream action that they have undergone at Lara makes us, however, incline to the former, and therefore in the table below, they are placed in that series.

If our conclusions are correct as to the succession of the beds, then, since the Newer Basalt is not represented in the Sorrento bore records, there may be an unconformity or disconformity in the Pleistocene rocks recorded by that bore, which may indicate pauses in the downward movement of the rocks and also erosion during the whole or portions of those pauses.

In view of the possibility suggested above that some of the sediments, hitherto found to be unfossiliferous, may be of the same age as the Portarlington beds, a protracted search for fossils in the sediments mentioned is required, and evidently the most likely places are the calcareous portions (if any), since it is in those portions of the Portarlington beds that most of the fossils occurring there have been found. The fossiliferous rocks of the Moorabool viaduct section, those of Kalimnan age at Lake Connewarre (Coulson, 1935, p. 3), those at Frankston of Janjukian age (Chapman, 1921, p. 11), and those of the Glenelg River of Werrikooian age (Singleton, 1935, p. 132), are or were (the Frankston beds having been changed into ironstones) calcareous.

It is of interest to note that, in the sections at Portarlington dealt with in this paper, the Balcombian, Janjukian, Kalimnan, and Werrikooian are missing.

Subdivision of the Post-Tertiary Rocks of the Port Phillip Bay District.

We now tabulate the results of the preceding remarks as a basis for further observation and discussion, and suggest the following subdivisions:—

1. *Lower Pleistocene.*—(i) The marine beds of the Steele's Rock and Pier sections, Portarlington. (ii) The ochreous sandy clays between 490 feet and 520 feet of the Sorrento Bore. (iii) (?) The Moorabool viaduct upper beds, these being somewhat older than the Portarlington beds. (iv) Probably some of the sediments, hitherto found to be unfossiliferous, overlying the fossiliferous Tertiary rocks of the Bellarine Peninsula, the eastern side of Port Phillip Bay, and generally around Melbourne.

Uplift and deep erosion, with the formation of pre-Newer Basalt valleys.

2. *Middle Pleistocene.*—Period of extrusion of the greater portion of the Newer Basalt series, followed by the deposition of the freshwater limestones of Lara and Limeburners' Point, Geelong.

Mostly subaerial. Probably a comparatively short period. Deep erosion, with formation of post-Newer Basalt valleys.

3. *Upper Pleistocene.*—Lower portions of the Dune Limestone of the Sorrento Peninsula, Queenscliff, Point Lonsdale, and Barwon Heads. Characterized by the presence of an extinct kangaroo (Gregory, 1901).

4. *Holocene.*—(i) Upper portions of the Dune Limestone. No line of demarcation has yet been ascertained between the upper and lower portions of this limestone.

Erosion (of the Dune Limestone mainly by marine abrasion) followed by (ii) The marine beds fringing the coast of Port Phillip Bay at the localities indicated above; and the latest alluvium, sand dunes, and swamp deposits.

In conclusion, we desire to acknowledge our indebtedness to Mr. F. Chapman, A.L.S., F.G.S., and Mr. F. A. Singleton, M.Sc., for their criticism of this paper.

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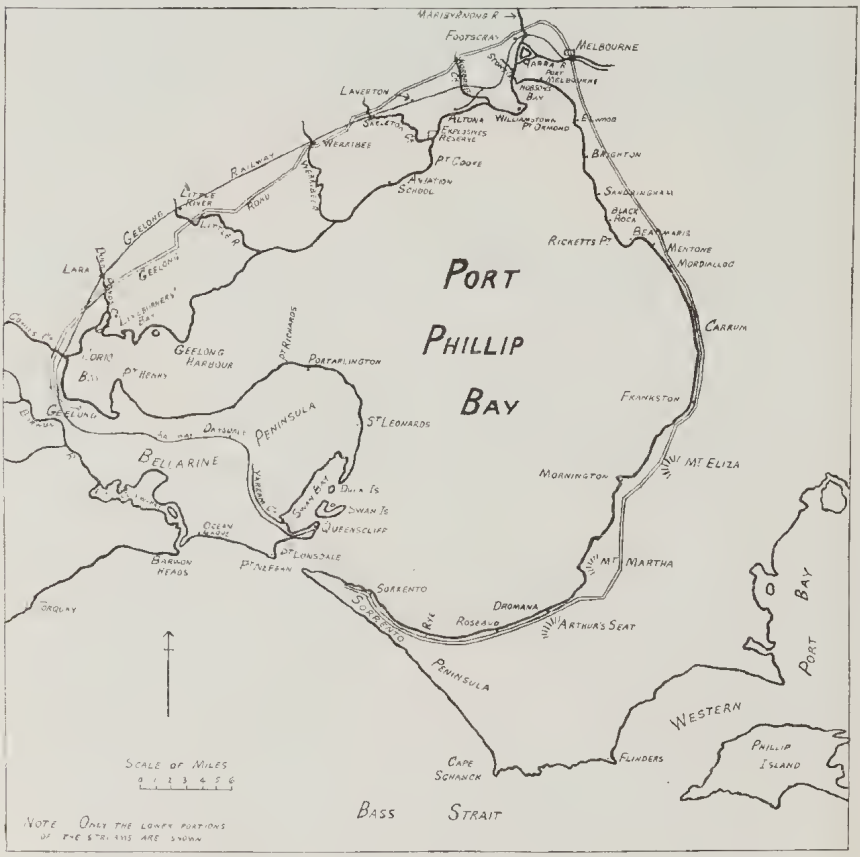

Fig. 3. Port Phillip Bay, showing most of the places referred to in the text.